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Greater Sage-Grouse Resource Selection Drives Reproductive Fitness Under a Conifer Removal Strategy☆

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ABSTRACT

The link between individual variation in resource selection (e.g., functional response) and fitness creates a foundation for understanding wildlife-habitat relationships. Although many anthropogenic activities adversely affect these relationships, it is largely unknown whether projects implemented to benefit wildlife populations actually achieve this outcome. For sagebrush (*Artemisia* spp.) obligate species such as the greater sage-grouse (*Centrocercus urophasianus;* sage-grouse), expansion of juniper (*Juniperus* spp.) and pinyon-pine (*Pinus* spp.; conifers) woodlands into sagebrush ecosystems has been identified as a conservation threat. This threat is intensified when a sagebrush ecosystem is bounded by naturally unsuitable habitats. As such, federal, state, and private land managers have implemented landscape-level management to remove conifers on thousands of hectares of sagebrush habitat across the western United States. Despite the scale of contemporary conifer treatments, little was previously known whether sage-grouse will occupy these manipulated landscapes and whether occupancy has consequences on fitness components. To address these questions, we monitored nest and brood success rates for 96 radio-marked sage-grouse from 2012-2015 that inhabited conifer-dominated landscapes in the Box Elder Sage-grouse Management Area in Utah where mechanical conifer removal projects were completed. We then linked sage-grouse resource selection to individual nest ($n = 95$) and brood ($n = 56$) success by incorporating random-slope Resource Selection Functions as explanatory predictors in a logistic brood success model. Using the novel approach of random slope covariates, we demonstrated that sage-grouse selected for nest and brooding sites closer to conifer removal areas and that the probability of individual nest and brood success declined ($\beta = -0.10$ and $\beta = -0.74$, respectively) as sage-grouse females selected sites farther from conifer removal areas. Our research provided the first evidence that mechanical conifer removal treatments can increase suitable available breeding habitats for female sage-grouse and that individuals who occupied these areas experienced enhanced nest and brood success.

Introduction

The link between resource selection and individual fitness is a key tenet in population ecology (DeCesare et al., 2014). Resource selection is the product of trade-off decisions in which animals address competing demands such as forage acquisition and predator avoidance in an effort to maximize fitness (Beyer et al., 2010; Leclerc et al., 2015). As such, resource selection is a multidimensional ecological process that occurs across both time and space (DeCesare et al., 2012). Furthermore, environmental resources are not distributed evenly across the landscape (Mysterud and Ims, 1998); therefore, individuals are likely to vary in their selection of resources, referred to as a *resource selection functional response* (Mysterud and Ims, 1998). This multidimensional process, depending on resource importance and availability, may drive individual differences in fitness.

In human-altered systems, functional responses in resource selection have been directly linked to reduced fitness (Benson et al., 2015; Hebblewhite and Merrill, 2008). As such, land managers seek to implement habitat improvement projects to mitigate the adverse effects of anthropogenic activities on wildlife populations (Fedy et al., 2014; Williams et al., 2004). However, it is uncertain whether wildlife populations respond to habitat manipulations on temporal and spatial scales that are relevant to managers (Knick et al., 2014). Although wildlife

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may occupy areas where landscapes have been manipulated to increase the available habitat space, little is known how increased habitat availability or space affects individual fitness or population abundance (Cain et al., 2008; Guthery, 1997; Harrington et al., 1999).

In 2010, the greater sage-grouse (*Centrocercus urophasianus;* sage-grouse) was designated as a candidate species by the US Fish and Wildlife Service (USFWS) for protection under the Endangered Species Act (ESA) of 1973 due to range-wide population declines that were attributed to long-term habitat losses and degradation (USFWS, 2010). In 2015, the USFWS determined that ESA protection for the sage-grouse was unwarranted because range wide efforts had sufficiently mitigated the previously identified species conservation threats (USFWS, 2015). These efforts included conifer removal, in particular, pinyon pine (*Pinus* spp.) and juniper (*Juniperus* spp.). The expansion of these conifers into sagebrush (*Artemisia* spp.) ecosystems was identified as a species conservation threat by the USFWS (2013) and several state-specific conservation plans (Idaho Sage-grouse Advisory Committee, 2006; Montana Sage Grouse Work Group, 2005; State of Nevada Sagebrush Ecosystem Council, 2014; State of Wyoming Game and Fish Commission, 2003; Utah Governor's Office, 2013). Stiver et al. (2006) estimated that 60 000 − 90 000 ha of sagebrush habitat across the range of sage-grouse is lost annually to conifer encroachment due to climate change and suppressed fire regimes (Miller and Eddleman, 2000). An estimated 90% of this expansion has occurred in areas that were previously sagebrush ecosystems (Miller et al., 2011).

Because of the impact of conifer expansion on sage-grouse (Baruch-Mordo et al., 2013; Casazza et al., 2011; Commons et al., 1999), managers have increasingly implemented management actions designed to remove or reduce conifer canopy cover in sagebrush habitats. The Natural Resources Conservation Service (NRCS), through its Sage-grouse Initiative (www.sagegrouseinitiative.com), has provided cost-share to landowners to mechanically remove or reduce thousands of hectares of conifer on private lands in the western United States (NRCS, 2015). Similar projects have been implemented range wide on Bureau of Land Management (BLM)- and US Forest Service (USFS)-administered lands. In Utah alone, conifers have been removed from > 200 000 hectares of sagebrush landscapes since 2006 under the Utah Department of Natural Resources (UDNR) Watershed Restoration Initiative (WRI; UDNR, 2014). Despite the scale and cost of these conifer treatments, little was previously known whether sage-grouse will occupy these manipulated landscapes and, if so, whether occupancy had fitness consequences (Connelly et al., 2011).

Large-scale mechanical conifer reduction projects are relatively low cost on a per-hectare basis and may have potential for increasing usable habitat space for sage-grouse and other sagebrush obligate species (Baruch-Mordo et al., 2013; Hanser and Knick, 2011; UDWR, 2009). The best available information shows sage-grouse avoidance of increasing conifer canopy cover (Baruch-Mordo et al., 2013; Commons et al., 1999; Doherty et al., 2008; Frey et al., 2013) and subsequent occupancy of areas where conifers have been removed (Commons et al., 1999; Frey et al., 2013; Cook, 2015; Sandford et al., 2015; Sandford 2016). Concomitantly, Casazza et al. (2011) demonstrated that sage-grouse habitat selection and subsequently fitness were related to conifer encroachment. However, it was unknown whether conifer removal would further increase reproductive fitness. Connelly et al. (2011) suggested that to effectively mitigate sage-grouse conservation threats, managers need better information regarding sage-grouse nest initiation rates, nest and brood success, survival, recruitment, production, seasonal movements, and habitat-use patterns in response to management actions.

To address this knowledge gap, we used a Resource Selection Function (RSF) framework to estimate individually marked female sage-grouse resource selection in relation to conifer removal projects during the reproductive period (nesting and brood-rearing). From this, we estimated how nest and brood success were influenced by individual variation in habitat selection (i.e., functional response in habitat selection). In our study area, conifer removal projects occurred across all phases of conifer-encroached sagebrush landscapes (Miller et al., 2005). These landscapes exhibited relatively intact sagebrush understory communities. Thus, we hypothesized that in these areas, sage-grouse females that selected nest and brood sites in close proximity to large-scale conifer removal areas and areas with lower existing conifer cover would also be more successful because of increased herbaceous cover (Roundy et al., 2014) and reduced predation risks (Commons et al., 1999). Consequently, the female's behavior could contribute to the potential for population level effects.

Methods

Study Area

Our study area was located in the Box Elder Sage-grouse Management Area (SGMA; Fig. 1; Utah Governor's Office, 2013) and the southeast corner of the Snake River Plain Management Zone (Stiver et al., 2006). The Box Elder SGMA encompasses one of the largest and most stable sage-grouse populations in Utah; 577 male sage-grouse were counted on 42 leks in 2013 (Utah Division of Wildlife Resources [UDWR] unpublished data; Western Association of Fish and Wildlife Agencies, 2015). The focal area covers approximately 103 600 ha in the vicinity of the towns of Park Valley (lat. 41°49′16″N, long. 113°24′03″W) and Rosette, as well as the former towns of Rosebud and Dove Creek in western Box Elder County, Utah, and includes all seasonal sage-grouse habitats (Dahlgren et al., 2016a). The sage-grouse population is largely bounded geographically by the Raft River Mountains to the north, the Grouse Creek Mountains to the west, and the Great Salt Lake Desert to the south and east (Cook, 2015). The area is a mix of private and public land and predominantly used for domestic livestock and alfalfa (*Medicago sativa*) hay production. Utah School and Institutional Trust Lands Administration-, BLM-, and USFS-administered lands are interspersed throughout, creating a mosaic of jurisdictions and land uses.

The study area was composed primarily of sagebrush-steppe habitat characterized by big (*A. tridentata* spp.) and small sagebrush (*A. nova* and *A. arbuscula*). Dominant understory grasses included Sandberg's bluegrass *(Poa secunda),* cheatgrass *(Bromus tectorum),* crested wheatgrass *(Agropyron cristatum),* and bluebunch wheatgrass *(Pseudoregnaria spicata).* Common forbs included milkvetch (*Astragalus* spp.), phlox (*Phlox* spp.), hawksbeard (*Crepis* spp.), lupine (*Lupinus* spp.), and western yarrow *(Achillea millefolium).* Native and invading conifer (pinyon-juniper; PJ) woodlands were present throughout the study area. Spruce (*Picea* spp.), fir (*Abies* spp.), quaking aspen *(Populus tremuloides),* and curl-leaf mahogany *(Cercocarpus ledifolius)* communities were found at higher-elevation areas throughout the study area. Elevation ranged from 1 350 m to 2 950 m. Mean annual precipitation was 177 mm at 1 447 m (Western Regional Climate Center [WRCC], 2015) and ranged up to 783 mm at 2 745 m (Utah Climate Center [UCC], 2016). Mean monthly lows of - 12 ° C and – 8 ° C occurred in January at 1 477 and 2 745 m, respectively (Beyer, 2015; Sandford, 2016). Mean monthly highs of 33°C and 21°C occurred in July at 1 477 and 2 745 m, respectively (Beyer, 2015; Sandford, 2016).

Conifer removal projects in the study area were first initiated ~30 yr ago. However, because of little maintenance, conifers have recolonized and expanded beyond the previous removal areas (Box Elder Adaptive Resources Management Working Group, 2007). In 2008, conifer removal projects in the study area increased in both size and frequency. Since 2008, nearly 8 100 ha of conifer canopy cover in the study area have been removed through active management (e.g., one- and two-way chaining, lop-and-scatter, and mechanical mastication). All sites exhibited relatively intact sagebrush communities. The project areas were also reseeded with mixtures of native and introduced high-production grasses and forbs to prevent invasive weeds (e.g., cheatgrass; *Bromus tectorum*) from establishing in newly disturbed soils (UDNR, 2014).

Sage-grouse Radio-marking

From 2012 to 2015, we captured, radio-marked, and monitored 96 female sage-grouse in our study area. Sage-grouse trapping occurred